

## COVER SHEET

### Access 5 Project Deliverable

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#### **Abstract:**

The purpose of this document is to present the findings that resulted from a high-level analysis and evaluation of the following documents:

- The OEP (Operational Evolution Plan) Version 7 – a 10-year plan for operational improvements to increase capacity and efficiency in U.S. air travel and transport and other use of domestic airspace. The OEP is the FAA commitment to operational improvements. It is outcome driven, with clear lines of accountability within FAA organizations. The OEP concentrates on operational solutions and integrates safety, certification, procedures, staffing, equipment, avionics and research;
- The Draft Flight Plan 2006 through 2010 – a multi-year strategic effort, setting a course for the FAA through 2001, to provide the safest and most efficient air transportation system in the world;
- The NAS System Architecture Version 5 – a blueprint for modernizing the NAS and improving NAS services and capabilities through the year 2015; and
- The NAS-SR-1000 System Requirements Specification (NASSRS) – a compilation of requirements which describe the operational capabilities for the NAS.

The analysis is particularly focused on examining the documents for relevance to existing and/or planned future UAV operations. The evaluation specifically focuses on potential factors that could materially affect the development of a commercial ROA industry, such as:

- Design limitations of the CNS/ATM system,
- Human limitations,

The information presented was taken from program specifications or program office lead personnel.

**Status:**

SEIT-Approved

**Limitations on use:**

*This document represents thoughts and ideas of the Implementation and Infrastructure work package team. It has been reviewed and approved by the SEIT but has not been reviewed or approved by the Project Office as official Access 5 Project recommendations on this subject.*



# **Remotely Operated Aircraft (ROA) Impact on the National Airspace System (NAS) Work Package, 2005**

## **Composite Report on FAA Flight Plan & Operational Evaluation Plan Version 7.0**

*The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.*

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# 1 EXECUTIVE SUMMARY

From an extremely simplistic assessment-level of the FAA Flight Plans of 2005 and 2006 (DRAFT), Unmanned Aerial Vehicles (UAV is FP terminology) are included under the “Increased Safety Section” and book-marked within the General Aviation (GA) initiative.

Similarly, the FAA Business Plans 2005 identifies that the Regulation & Certification Group will lead the UAV activities and the Air Traffic Organization will be in support.

The Operational Evolution Plan V 7.0 continues to stress overall NAS safety, capacity and efficiency in the air and ground environment, however, it does leave “the door open” for UAVs. This “door” is provided not in the quadrants dedicated to congestion and efficiency but in the outer-rings identifying “Prototype & Pilot Projects” and/or “Safety, Policy, Procedures & Airspace” and any new UAV initiative would be introduced by industry representation through the appropriate RTCA committee.

Unfortunately this simplistic assessment is insufficient to really understand the UAV-related relevance of the various FAA planning and funding documents and this report is designed to provide both content and context in this regard.

From an Air Traffic Management (ATM) perspective the (total) integration of UAVs is bound to cause some intellectual as well as technical and operational challenges, since regulators and the ATM community have not yet had the opportunity to become thoroughly familiar with the fundamentals of possible UAV integration and a baseline for comparison with manned aircraft operations has not yet been fully explored.

Using the RTCA Concept of Operations & Future Vision for the Future of Aviation (Nov 15, 2002) as a baseline for consideration, we can identify some similarities with manned aircraft operations and point out some definite differences.

The Con Ops vision “... is to allow users to make operational decisions based on their own economic business case while enabling the safe, orderly and expeditious flow of air traffic ...to maximize benefits and achieve seamless operations”. It goes on to state, “... aircraft operate along more efficient auto-negotiated four dimensional flight profiles. Operations are increasingly aircraft-centric, focusing on performance rather than equipment standards; with use of required navigation performance (RNP) as a key step in enabling greater efficiency, flexibility and capacity enhancements.”

There is tacit recognition that the future ATM system will be data-driven and that the adoption of a “system wide information management (SWIM)” will be required to manage the complex and dynamic demands of the NAS stakeholders.

UAVs could impose an additional, unique set of considerations on a system that has been constructed to support only humanly managed flight operations. The entire investment

strategy for NAS evolution is based upon the current airline-centric operational model of point-to-point operations whereby ATC accommodates user-preferred routes whenever possible. The name of the game is throughput by maximizing predictability and flexibility and making the most of the current NAS capacity. The air traffic controller's work-load has increased with the overall shift from large jets to smaller regional jets and the investment in ATC automation tools support this same concept of operations.

The obvious differences in UAV operations from manned aircraft operations are in three main areas:

**Flight Envelope & Performance** – UAVs range from the micro (light weight) through to roughly the size of a Boeing 737. There is a direct relationship between airframe size and power-plant selected to achieve its operating role and mission requirements. UAVs have widely varying power-plants, turbo-fan, turbo-propeller, normally aspirated gas engines; and a few with hybrid solar or alternative fuel systems. In addition, the power output of the electrical generators often dictates the equipment that can safely be powered, including considerations for anti-icing and de-icing. The ratio of thrust to weight dictates the rate of climb, maneuverability, service ceiling and the various operating speeds, just the same as manned aircraft. Often these operating parameters are different from those of the current NAS operators.

**UAV Levels of Automation & Sophistication** – the current UAVs in operation have widely varying capabilities for C3 and other operational considerations, like the ability to utilize RNP and Reduced Vertical Separation Minima (RVSM). Some UAVs rely on human observers to provide a level to see (or sense) and avoid other traffic, others utilize on-board electronic sensors. The C3 capabilities can range from basic line-of-sight VHF/UHF to sophisticated satellite-based relay channels with associated back-up systems. The flight management systems also vary widely and with the expectation that "aircraft" will follow pre-defined four dimensional trajectories, in many cases some accommodation for UAV must be expected.

**Mission Profiles** – the current mission profiles anticipated for UAVs initially are for homeland defense and border or port surveillance. The flight profile could entail a take-off, not necessarily from a conventional runway, a climb and transit to a "target area", a change in altitude from high to low to medium, a loitering requirement and possibly a return to base or onward transit to another destination. Recovery could entail a sky-hook, or some other unconventional landing system. With the exception of transit flights, it is envisaged that UAVs would be operated very rarely in the conventional point-to-point manner for which the NAS is designed, funded and maintained/evolved.

FAA plans, including the Operational Evolution Plan, the Flight Plan, the NAS System Architecture, and the NAS System Requirements Specifications have been examined to safely expand the use of UAVs and understand potential effects of the development of a commercial UAV industry.



Of particular interest are design and/or human limitations and their impact on the ability to meet NAS communications, navigation, surveillance, and air traffic management requirements in the light of the vast array of systems and tools in use today.

It can be anticipated that air traffic will increase as UAV applications become more pervasive; and newer systems will replace capacity-constrained, older technology systems to more safely accommodate the larger volume of air traffic in the NAS.

Surveillance and automation systems such as ADS-B, ASDE-X, STARS, ERAM, and ATOP, together with new voice and data communications platforms, will develop enhanced capacity to meet NAS requirements for the 21<sup>st</sup> century.

New strategies, methods and tools for handling traffic flow, such as URET, will also need to be devised to adapt to the higher volume, safety levels and reduced separation demanded in the future. To this end, recommendations for further study in the areas of modeling, decentralizing and relocation of facilities are also made in this document.

A high performance air transportation system supports our objective of fueling our economy by allowing access to a wide range of private, commercial, civil and military aviation users, while remaining the world's safest form of transportation.

As an FAA executive has remarked in many a public forum, the FAA consider safety as their priority/benchmark for operating the NAS and will endeavor to introduce UAVs in a manner that first, "does no harm"; and the approach adopted by the FAA to this challenge will be "prudent, pragmatic and progressive"!

It is clear from the structured analysis of the various FAA investment documents examined in this work package that UAVs can be successfully introduced to the NAS if the Access 5 program continues to provide the empirical data required to substantiate the conclusions being drawn by the project and resulting in recommendations to the FAA.

Given that the NAS has now surpassed the pre-2001 levels of traffic and placing increasing demands on what is overall a thirty-year old infrastructure, these documents identify an investment strategy that is heavily reliant on total system automation. This underlying theme must be factored into future Access 5 activities if it to stay aligned with how the NAS will be funded, evolved and operated in the years to come.

Note:

It should be noted that the nomenclature related to the term Unmanned Aerial Vehicle (UAV), Remotely Operated Aircraft (ROA) and Unmanned Aircraft System (UAS) are used interchangeably to reflect the genre and vintage of the various documents studied and/or referred to.

## **2 PURPOSE**

The purpose of this document is to present the findings that resulted from a high-level analysis and evaluation of the following documents:

- The OEP (Operational Evolution Plan) Version 7 – a 10-year plan for operational improvements to increase capacity and efficiency in U.S. air travel and transport and other use of domestic airspace. The OEP is the FAA commitment to operational improvements. It is outcome driven, with clear lines of accountability within FAA organizations. The OEP concentrates on operational solutions and integrates safety, certification, procedures, staffing, equipment, avionics and research;
- The Draft Flight Plan 2006 through 2010 – a multi-year strategic effort, setting a course for the FAA through 2001, to provide the safest and most efficient air transportation system in the world;
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The analysis is particularly focused on examining the documents for relevance to existing and/or planned future UAV operations. The evaluation specifically focuses on potential factors that could materially affect the development of a commercial ROA industry, such as:

- Design limitations of the CNS/ATM system,
- Human limitations,

The information presented was taken from program specifications or program office lead personnel.

## **3 BACKGROUND**

### **3.1 Historical**

In the late 1970s the FAA and DoD jointly developed criteria that enabled ROA to operate outside restricted area airspace. Initial ROA systems were small and operated in proximity to the operator. The advent of the Predator ROA in 1995 expanded the scope of ROA operations to greater distances and higher altitudes. The arrival of the Global Hawk ROA in 1998 stretched the bounds of operation to the international arena. Increasingly, air space capacity and safety issues are becoming of major importance as rapidly growing unmanned flight activity is anticipated.

### **3.2 Policies, Procedures and Technical Standards**

NASA's High-Altitude, Long-Endurance Remotely Operated Aircraft in the National Airspace System (HALE ROA in the NAS) project was established in 2004 to develop policies, procedures and technical standards to enable remotely or autonomously operated aircraft to fly reliably and routinely in civil airspace with an equivalent level of safety as planes flown by on-board pilots. The project forms the core of the government-industry Access 5 project, bringing together NASA, the FAA, the DoD, the Department of Homeland Security (DHS) and the UAV National Industry Team (UNITE) to integrate ROAs into the national airspace.

### **3.3 Remote Pilots**

Remote pilots operate ROAs from distant vantage locations that may either be fixed or mobile, and are equipped with advanced technological means to achieve mission objectives. The remote pilots typically require communications capacity to remotely operate aircraft controls and equipment, and successfully conduct routine or special flight activities. Remote pilots make extensive use of traditional flight methods and techniques, air navigation, meteorology, flying directives, and aircraft operating procedures, throughout short or extended flights, from locations often coordinated to be geographically distant from the aircraft being flown.

As expected, for certain flight segments, remote pilots rely extensively on air traffic controllers as well as automated air traffic control systems, locally available to the aircraft. To achieve this end, the remote pilots communicate with air traffic controllers either through the use of a “bent pipe” (Pilot-to-ROA-to-air traffic controller), or possibly, through the use of the PSTN (Public Switched Telephone Network) or cellular telephone networks.

### **3.4 Special Committee (SC) 203**

Standards associated with ROAs, with safety being a primary emphasis, are being developed by SC203, with the active involvement of all impacted FAA lines of business.

## 4 STATED ASSUMPTIONS

The evaluation of NAS subsystem design limits must be assessed based on NAS traffic models and traffic added by ROA operations.

Main assumptions made in this document are based on a model that shows that air traffic volumes will increase significantly as ROA applications and operations become more common and widespread – in other words, ROA operations do not displace manned flight operations but add to it. Consequently, the effects of vast increases in air traffic volume are examined – most particularly on air traffic controllers – as well as on surveillance, communications, and automation systems. The impact ROA traffic will have on Air Traffic Controllers and Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) are examined next.

Excerpts from the “FAA Forecast Fact Sheet Fiscal Years 2004-2015” [ 1], are provided in Figure 4-1 and Figure 4-2.

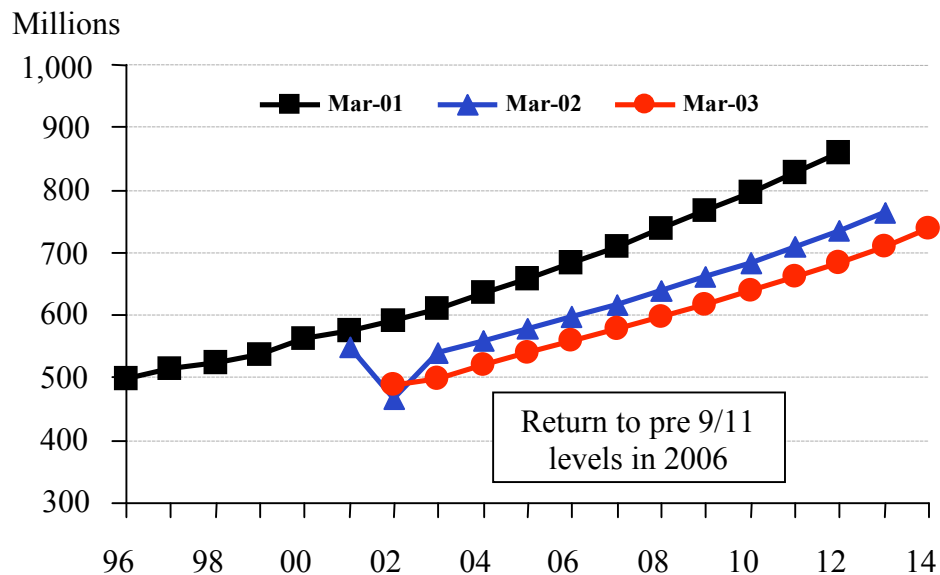
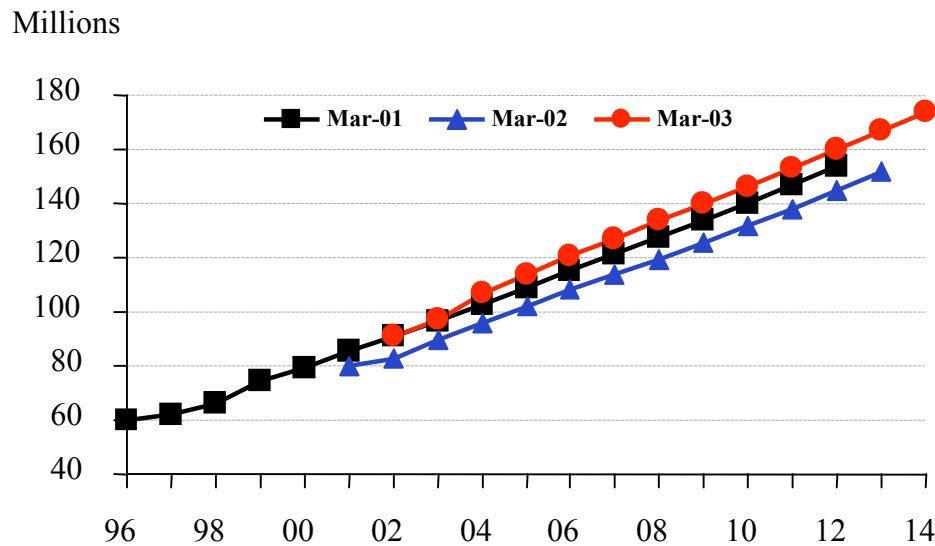


Figure 4-1. Domestic Large Carrier Enplanements



**Figure 4-2. Commuter Enplanement**

#### **4.1.1 Traffic from a Terminal Perspective**

Increased airspace capacity around major airports, reducing delays and improving air safety requires high performance/capacity surveillance systems coupled with high levels of automation. Based on current technology, for a given geographic area, airspace capacity around terminal areas are sometimes augmented by commissioning multiple runways.

Under FAA current regulations, a new runway can allow at least 30 to 40 more operations per hour. Therefore, airport capacity to handle air traffic is a function of airport size, runway layout, air traffic patterns (both arriving and departing), ambient weather conditions, and the time frame in which a surge of traffic must be dealt with.

## **5 ROA POTENTIAL APPLICATIONS**

Based on sensor and other developments recently seen, ROA applications likely to be deployed on large scales are:

- Mineral exploration;
- Border and coast surveillance;
- Media resources;
- Environmental control and monitoring;
- Telecommunications;
- Crop and aquaculture farm monitoring;
- Cargo delivery;
- Unexploded ordnance detection;
- Ordinance delivery; and
- Other law enforcement activities

When airspace is shared, ROAs and/or their pilots, need to accurately detect other aircraft to ensure safety and conflict resolution at the same level as manned aircraft. Since some aircraft do not have Mode S or ATCRBS transponders, other forms of sensors may be needed for situational awareness of the airspace around the vehicle. ROAs that operate in positively controlled airspace are assumed to have at least a Mode C transponder.

## 6 ATC AUTOMATION

The following sections examine the effects of high levels of air traffic, from the following perspectives:

- Oceanic, including ATOP
- En route, including HCS, ERAM, and Micro-EARTS
- Terminal, including Common ARTS, and STARS
- Surface, including ASDE-X
- Flight service, including OASIS

### 6.1 Microprocessor-En Route Automated Radar Tracking System (Micro-EARTS)

Micro-EARTS is a radar processing system implemented with Commercial Off-The-Shelf (COTS) equipment, for use in both En Route and Terminal environments. Additionally, Micro-EARTS supports a combination of Oceanic and En Route functions in Anchorage, AK.

Micro-EARTS provides single sensor and a mosaic display of traffic and weather using long- and short-range radars. The FAA is investigating incorporating NEXRAD Doppler radar weather data onto Micro-EARTS displays at various sites. At Anchorage, Alaska, Micro-EARTS also provides Automatic Dependent Surveillance-Broadcast (ADS-B) surveillance and display. Micro-EARTS interfaces with multiple types of displays, including Display System Replacement (DSR), Digital Bright Radar Indicator Tower Equipment (DBRITE), and the flat panel tower controller displays; to provide controllers with:

- the situation display, to assist in safely controlling air traffic
- weather information, both from surveillance radar and from Next Generation Radar (NEXRAD) radars

FAA Micro-EARTS are operational in Anchorage, Honolulu, Guam, and San Juan. Additionally, there are four Micro-EARTS operated by the DoD.

ATOP (Advanced Technologies and Oceanic Procedures) will replace the Anchorage Micro-EARTS, STARS will replace the others.

Table 6-1 shows system capacity figures for the Micro-EARTS system [ 2].

**Table 6-1. Micro-EARTS System Capacity Figures**

Data Item	Quantity
Number of sensors	50
Number of active data files	1500
Number of aircraft	500
Number of flight plans	500
Number of controller positions	50
Number of data blocks/display	300
Number of tracks/display	500
Number of airports and fixes	63
Number of configuration items	5
Number of altimeter stations	255
Number of MSAW polygons	800
Size of system plane (Note: 2048 NM by 2048 NM is the current certified maximum)	more than 2048

## **6.2 Common Automated Radar Tracking System (ARTS)**

Common ARTS operational deployment began in 1997, to be the primary Terminal automation system until it is replaced with STARS. ARTS programs have a common air traffic control mission with functional requirements similar to STARS, such as the ability to support simultaneous multiple radar displays and adapt to site changes. Common ARTS provides identical COTS microprocessors and software developed in a high order language. Common ARTS has been implemented at 149 small-to-medium-sized TRACONs and ARTS IIE systems and at 5 large TRACONs as ARTS IIIE systems.

Information on scalability and architectural limitations is provided in Table 6-2 for ARTS IIE and in Table 6-3 for ARTS IIIE [ 14].

**Table 6-2. ARTS IIE Scalability and Architectural Limitations**

Data Item	Quantity
Number of simultaneously tracks	256 (one-sensor configuration) 512 (two-sensor configuration)
Number of Sensors (short and long range radars)	1 or 2
Number of color displays	22



**Table 6-3. ARTS IIIE Scalability and Architectural Limitations**

Data Item	Quantity
Number of simultaneous tracks	10,000
Number of Sensors (short and long range radars)	15
Number of color displays	200
Number of remote tower interfaces	11
Covered geographical area (square miles)	23,000

### **6.3 Standard Terminal Automation Replacement System (STARS)**

The Standard Terminal Automation Replacement System (STARS) is a joint Federal Aviation Administration (FAA) and Department of Defense (DoD) program to replace Automated Radar Terminal Systems (ARTS) and other capacity-constrained older technology systems at 172 FAA and up to 199 DoD terminal radar approach control facilities and associated towers.

STARS receives radar data and flight plan information and presents the information to air traffic controllers on high-resolution color displays, enabling the controller to monitor, control, and accept hand-off of air traffic.

- Radar data can be received from ASR-11 systems, including surveillance, weather, and system status.
- ASR-11 radar systems typically have a capacity of 700 targets minimum in a single scan.

In terms of capacity, STARS systems [ 15] are expandable to be capable of:

**Table 6-4. STARS Scalability and Architectural Limits**

Data Item	Quantity
Number of airborne aircraft simultaneously tracked within a terminal area	1,350
Number of short and long range radar interfaces	16
Number of controller positions	128
Number of remote tower interfaces	20
Covered geographical area	400 by 400-mile

DoD STARS provides state-of-the-art air traffic control systems for managing terminal area airspace for the US military and in some configurations can include over 100 RAPCON (Radar Approach Control) facilities with 50 associated towers and 20 stand-alone towers.

STARS also can of display six distinct levels of weather data and intensities (approved by the National Weather Service, and identified by different colors) simultaneously with air traffic, allowing controllers to direct aircraft around bad weather.

STARS is designed to accommodate air traffic growth and the introduction of new systems designed to contribute to the overall safety and efficiency of the NAS (National Airspace System).

#### **6.4 The Host Computer System (HCS)**

The HCS processes surveillance reports and flight plan information in the ARTCC. The Host/Oceanic Computer System Replacement (HOCSR) Phase 1 replaced the main processors of the HCS, Oceanic Display and Planning System, and Offshore Flight Data Processing System. Phase 2 up-leveled NAS software to operate in the Native System/390 mode and provides a common monitor for En Route and Oceanic. Phase 3 replaces the Direct Access Storage Devices (DASDs) and provided minimal monitor and control capability for the DASDs. Phase 4 replaces the remaining peripherals.

In terms of capacity, the load is largely a function of the number of tracks and the radar input load. As Flight Data Inputs, Track Control Messages, Flight Data Amendments, and Display Control Actions are created, capacity gets utilized on the HCS. Table 6-5 provides scalability and architectural limits for the HCS [ 3].

**Table 6-5. HCS Scalability and Architectural Limits**

Data Item	Quantity
Peak instantaneous number of tracks	600 $\pm$ 10%
Corresponding Number of active aircraft at a peak instant	1,100
Corresponding Number of pending flight plans at a peak instant	400
NAS maximum design value for flight plans in main memory	2,500

##### **6.4.1 User Request Evaluation Tool (URET)**

URET provides automated decision-support capabilities that enable air traffic controllers to better track en route aircraft and to predict air conflicts up to 20 minutes into the future. Additional flexibility in managing air traffic and increased route efficiency are achieved without compromising safety.

URET connects to the HCS through a one-way interface, to process real-time flight plan and track data from the ARTCC HCS, to automatically identify en route conflicts and assist air traffic controllers in responding to pilot requests for route changes in the en route airspace between airports.

Real-time flight plan and track data from the ARTCC HCS are combined with site adaptation, aircraft performance characteristics, and winds and temperatures from the National Weather Service in order to build four-dimensional flight profiles, or trajectories, for all flights within or inbound to the facility [ 4]. URET also provides a

“reconformance” function that adapts each trajectory to the observed speed, climb rate, and descent rate of the modeled flight. For each flight, incoming track data are continually monitored and compared to the trajectory in order to keep it within acceptable tolerances.

URET maintains “current plan” trajectories, i.e., those that represent the current set of flight plans in the system, and uses them to continuously check for conflicts. When a conflict is detected, URET determines which sector to notify and displays an alert to that sector up to 20 minutes prior to the start of that conflict. URET also provides a “trial plan” function. Trial planning allows a controller to check a desired flight plan amendment for potential conflicts before a clearance is issued.

In terms of scalability and architectural limitations, Table 6-6 describes the maximum number of flight plans URET currently accommodates, together with plans for increasing capacity within the next twelve months [ 21]. For URET to accommodate ROAs, aircraft characteristics are needed, such as:

- Climb / descent rates
- Maximum/Minimum air speed
- Etc.

**Table 6-6. Number of Flight Plans URET Accommodates**

Schedule	Number of Flight Plans
August 2005	2,500
August 2006	3,300

## **6.5 En Route Automation Modernization (ERAM)**

ERAM has been initiated to continue the modernization of the ARTCC automation software and completely replace the automation system for managing high-altitude traffic at 20 en route centers nationwide.

ERAM has three main components: 1) the En Route Communications Gateway (ECG) to replace the Peripheral Adapter Module Replacement Item (PAMRI), 2) the ERAM Back up System (EBS) to adapt the STARS fusion tracker to replace the Microprocessor-En Route Automated Radar Tracking System (MicroEARTS), and 3) the replacement of the HCS. In addition to replacing HCS, FAA expects ERAM to enhance the flow of air traffic by allowing for more flexible routing of aircraft.

HCS’s process and integrate complex flight plan information and radar data to provide air traffic controllers with aircraft identification and position information to control air traffic 24 hours a day, 365 days a year. According to the FAA, HCS hardware and software will reach end of useful life in the next 5 years (by 2010), in part because of increasingly difficult maintenance.

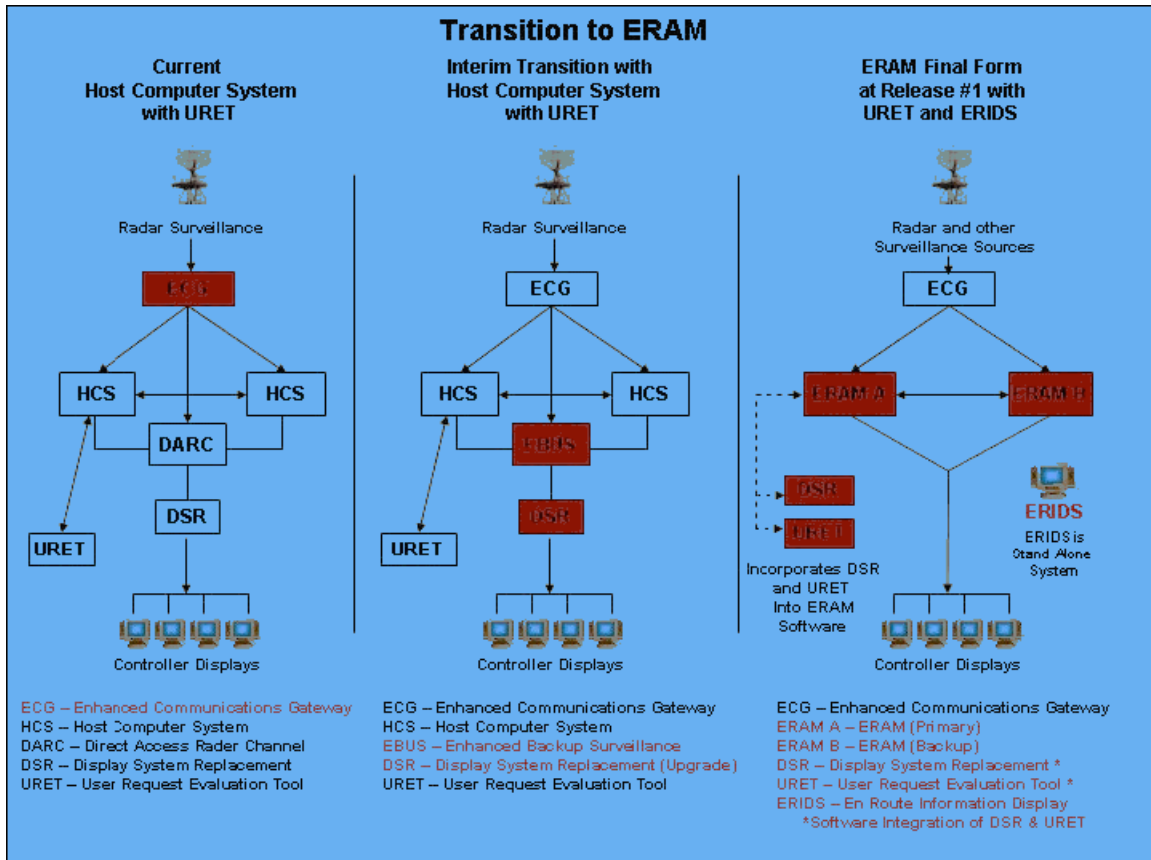
For the last 2 years, the bulk of the work has focused on replacing a backup system to the current Host computer. The new backup entered service in April 2005 at Denver [ 6].

Scalability and architectural limits [ 5] for the ERAM design are currently considered to be planned as outlined in Table 6-7 below.

**Table 6-7. ERAM Scalability and Architectural Limits**

Data Item	Quantity
Aircraft Types	1,500
Controlled Aircraft in Controlled Airspace	2,048
Uncontrolled Aircraft in Controlled Airspace	2,048
Flight Plans	65,536
Sectors	128
Fixes	100,000
Airways	4,096
Coded Routes	2,048
Arrival Routes	24,000
Departure Routes	24,000
Standard Terminal Arrival Routes (STARs)	670
Departure Arrival Routes	32,000
Major Airports	1,024
NAS Airports Identifiers (including Major Airports)	24,000
Altitude / Speed Restrictions	15,000
Special Activities Airspaces	3,000

The FAA's plan to transition from HCS to ERAM over the period covering FY 2005 to FY 2009 [ 6] is shown in Figure 6-1.



**Figure 6-1. FAA’s plan to transition from HCS to ERAM, FY 2005 to FY 2009**

## 6.6 Advanced Technologies and Oceanic Procedures (ATOP)

ATOP provides a fully modernized oceanic air traffic control automation system that better leverages investments made in cockpit digital communications.

With ATOP, the FAA significantly reduces the intensive manual processes that today limit the ability of controllers to safely handle airline requests for more efficient tracks or altitudes over long oceanic routes. In addition, it allows the FAA to meet international commitments of reducing aircraft separation standards thereby dramatically increasing capacity and efficiency. FAA-E-2955 covers aspects of the ATOP specification.

New York Center is the first of three oceanic air traffic control facilities to achieve full operational use of ATOP. Full operational use is expected at Oakland Center October 2005. After commissioning at Oakland, the FAA will have the automation, surveillance and communications to reduce aircraft separation from 100 nautical miles to 30. The schedule for deployment at the Anchorage Center is March 2006.

Scalability and architectural design limits for the ATOP system [ 22] are shown in Table 6-8. ADS-C enables appropriately equipped aircraft to send position information

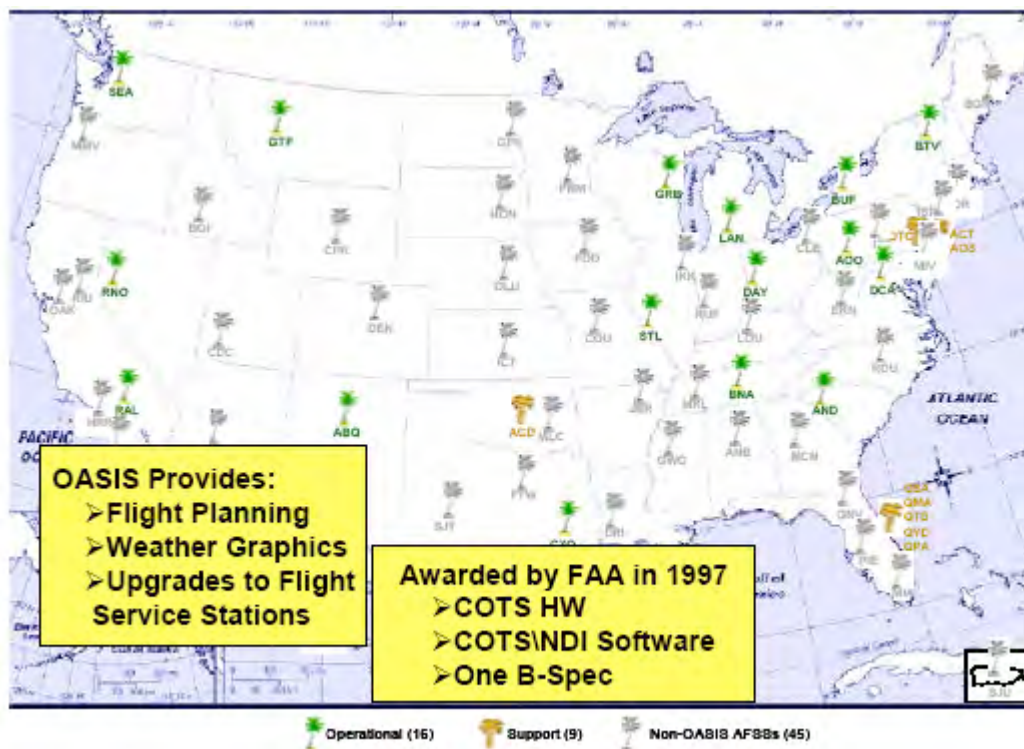
messages at predetermined geographical locations, at specified time intervals or at the occurrence of specified events. ADS-C can be relayed via SATCOM data link, or VHF data link.

**Table 6-8. ATOP Scalability and Architectural Limits**

Data Item	Quantity
Number of Flight Plans	1,000
Number of Active Flights	1,000
Number of Workstations	40
Number of Sectors	200
Number of ASDE-C contract messages	705
CPDLC messages per hour	630

## **6.7 Operational and Supportability Implementation System (OASIS)**

OASIS is designed to store weather information and to track warning messages for private aircraft; including alerting small-plane pilots when equipment at airports is malfunctioning. In addition, OASIS provides upgrades to Flight Service Stations. A general view of OASIS [ 7] is presented in Figure 6-2.



**Figure 6-2. General View of OASIS**

Information on OASIS may be superseded based on the A76 Flight Service Station contract award to Lockheed Martin.

## 7 COMMUNICATIONS

The NAS communications infrastructure encompasses extensive capabilities for providing voice and data communications throughout the NAS and with external facilities and government agencies. This document examines the air-ground, ground-ground interfacility and ground-ground intrafacility voice and data communications between:

- Aircraft
- air traffic control
- flight service facilities

also between:

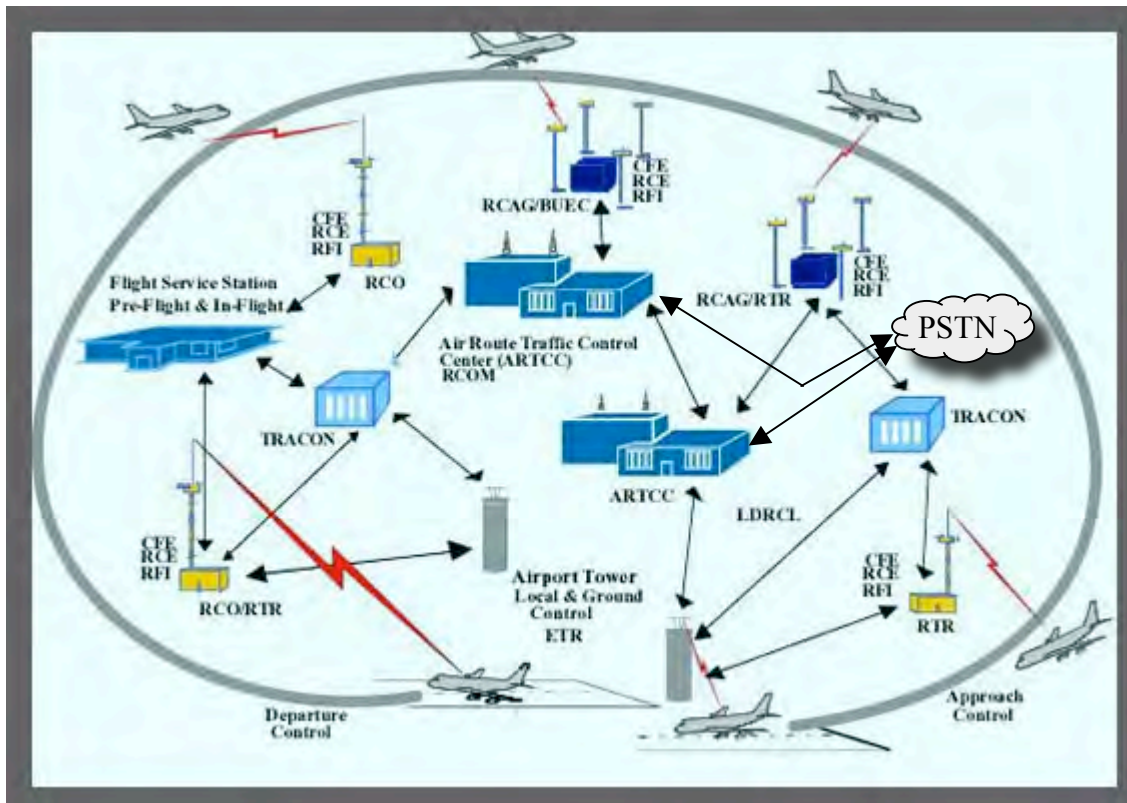
- FAA
- external facilities

and within:

- NAS facilities

A general view of the current ATC Air Ground communications solution implementation [ 16] is provided in Figure 7-1.





**Figure 7-1. ATC Air Ground communications solution implementation**

## 7.1 NAS Ground-Ground Interfacility Communications

The NAS supports communications capability between selected operating, supervisory, maintenance, and administrative positions at separate NAS facilities [ 17]. In general, the ground-to-ground system is sufficiently modular to allow capacity increases where call capacity limits are reached. Direct-access voice communications connectivity between specialists in one ATC facility and designated specialists in another facility is shown in Table 7-1 .

**Table 7-1. Interfacility Direct-Access Voice Connectivity**

<b>From</b>	<b>To</b>
ARTCC	Adjacent ARTCCs Associated ATCTs Associated AFSSs FAA Headquarters Operations Center ATCSCC
AFSS	Adjacent AFSSs Associated ARTCCs Associated ATCTs FAA Headquarters Operations Center ATCSCC
ATCT	Associated ARTCCs Adjacent ATCT/RAPCON Associated AFSSs FAA Headquarters Operations Center ATCSCC
FAA Headquarters Operations Center	Each ARTCC Each ATCT Each AFSS ATCSCC
ATCSCC	Each ARTCC Each ATCT Each AFSS FAA Headquarters Operations Center

For this type of connectivity, sufficient capacity needs to be maintained to ensure that the number of direct-access calls that are blocked because of saturation of equipment does not exceed 1 in 1000 calls.

Furthermore, the NAS supports additional direct-access voice communications connectivity for use within 2 minutes of a catastrophic failure in an ARTCC, as shown in Table 7-2.

**Table 7-2. Interfacility Direct-Access Backup Voice Connectivity**

<b>From</b>	<b>To</b>
ARTCC	Designated Non-Adjacent ARTCCs Designated ATCTs Associated with an Adjacent ARTCC Designated AFSSs Associated with an Adjacent ARTCC
AFSS	Designated ARTCC Adjacent to Primary ARTCC
ATCT	Designated ARTCC Adjacent to Primary ARTCC

In addition, there are requirements for each facility manager, supervisory and specialist position in an ARTCC, ATCT, AFSS, the FAA Headquarters Operations Center, and the ATCSCC to have indirect-access voice communications connectivity with other positions in selected facilities, as shown in Table 7-3.

**Table 7-3. Interfacility Indirect-Access Backup Voice Connectivity**

<b>From</b>	<b>To</b>
ARTCC	Adjacent ARTCCs Associated ATCTs Associated AFSSs ATCSCC FAA Headquarters Operations Center Airline Dispatch Offices Designated DoD Facilities Other NAS Facilities
ATCT	Associated ARTCC Associated AFSSs ATCTs Associated with same ARTCC ATCSCC FAA Headquarters Operations Center Airline Dispatch Offices Designated DoD Facilities Other NAS Facilities
AFSS	Adjacent ARTCCs Associated ATCTs AFSS Associated with same ARTCC ATCSCC FAA Headquarters Operations Center Airline Dispatch Offices Designated DoD Facilities Other NAS Facilities
ATCSCC	All ARTCCs, ATCTs, and AFSSs FAA Headquarters Operations Center Airline Dispatch Offices Designated DoD Facilities Other NAS Facilities Selected Federal and State Law Enforcement Agencies
FAA Headquarters Operations Center	All ARTCCs, ATCTs, and AFSSs ATCSCC Airline Dispatch Offices Designated DoD Facilities Other NAS Facilities Selected Federal and State Law Enforcement Agencies

As for direct-access, sufficient capacity for indirect-access connectivity needs to be maintained to ensure that calls that are blocked because of saturation of equipment cannot exceed 1 in 1000 calls.

Beyond these basic capabilities, clearly intelligible voice communications connectivity through interface with commercial communications networks is also provided, although the capacity to be maintained to ensure that calls that are blocked because of saturation of equipment is required to not exceed 1 in 20 calls.

The NAS provides data communications capabilities between NAS facilities as shown in Table 7-4.

**Table 7-4. NAS Interfacility Data Communications Connectivity**

<b>From</b>	<b>A R T C C</b>	<b>A T C T</b>	<b>A F S S</b>	<b>A T C S C C</b>	<b>FAA Hdqt Ops Ctr</b>	<b>Traffic Mgmt Fac</b>	<b>NAS Maint. Fac</b>	<b>Modes Data Link Fac</b>	<b>NAS Weather Fac</b>	<b>NAS Surv. Fac</b>	<b>Remote Comm. Fac</b>	<b>NAS Aids</b>	<b>NAS Weather Sensors</b>
ARTCC	x	x	x	x	x	x	-	x	-	-	-	-	-
ATCT	x	x	x	x	x	x	-	x	-	-	-	-	-
AFSS	x	x	x	x	x	x	-	x	-	-	-	-	-
ATCSCC	x	x	x	-	x	x	x	-	x	x	x	x	x
FAA Hdqt Ops Ctr	x	x	x	x	-	x	x	-	x	-	-	-	-
Traffic Mgmt Fac	x	x	x	x	x	x	x	-	-	-	-	-	-
NAS Maint. Fac	x	x	x	x	x	-	x	-	-	-	-	-	-
NAS Data Link Fac	x	x	x	-	-	-	x	x	-	-	-	-	-
NAS Weather Fac	x	x	x	x	x	x	-	-	x	-	-	-	-
NAS Surv. Fac	x	x	-	-	-	-	x	-	-	-	-	-	-
Remote Comm Fac	-	-	-	-	-	-	x	-	-	-	-	-	-
Nav Aids	-	-	-	-	-	-	x	-	-	-	-	-	-
NAS Weather Sensors	x	x	x	-	-	-	x	-	x	-	-	-	-

## **7.2 NAS Ground-Ground Communications Reconfiguration Capabilities**

The NAS provides reconfiguration capabilities [ 17], shown in Table 7-5, for the:

- Distribution of intrafacility and interfacility communications within ATC facilities
- Distribution of intrafacility and interfacility communications to permit an ARTCC to provide service in airspace normally served by a failed ARTCC
- Computer assisted and/or supervisory control of the reconfiguration capabilities for intrafacility and interfacility data communications at designated specialist positions with and ARTCC or an ATCT

**Table 7-5. Reconfiguration Capabilities**

VOICE	DATA	NORMAL	BACKUP	CAPABILITIES	FACILITIES
X	X	X	X	No transmissions interrupted	At all ATC facilities
X	-	X	X	No transmissions in queue lost	
X	X	X	X	No interference with positions not being reconfigured	
X	-	X	X	Menus and/or maps for changing individual or sets of voice features, including direct/indirect access connectivity	
X	X	X	X	Individual position reconfiguration by supervisor using menu or preset maps	
X	-	X	X	Single action reconfiguration for all positions at once after menu or preset map selection	At ATCTs and AFSSs
-	X	X	-	Computer-assisted reconfiguration of all positions in facility	At ARTCCs and ATCTs
X	X	X	-	Reconfiguration for training or changes in position responsibilities by supervisory command only	
X	-	X	X	Simultaneous 1 to 10 position reconfiguration by supervisor using selectable preset reconfiguration maps	At ARTCCs
X	X	-	X	Predefine and store up to 10 backup configurations	
X	X	X	X	Single action activation of the selected backup configuration	
X	X	-	X	Selected backup configuration operational within 2 minutes of ACE failure	

### 7.3 NAS Air-Ground Communications

VHF voice channels in the 117.975 to 136.000 MHz band and UHF voice channels in the 225 to 400 MHz band are utilized for air-ground voice communications coverage.

Generally, VHF and UHF voice channels are used for communications with civil and



military users, respectively. Special use frequency notches exist for UNICOM, Air-to-Air, Airline Flight following, ACARS, VDL-2, etc.

## **7.4 NAS Voice Switching Systems**

This section covers FAA voice switching capabilities, including VSCS, STVS and RDVS switching system capacity.

It would be interesting to note that for air-ground communications, radio frequencies are manually selected by a pilot when transitioning from one sector to another. Each sector has a unique radio frequency that the controller uses to communicate with the pilots. As aircraft transition from one sector to another, control responsibility is passed, and pilots are instructed to change to the frequency of the next sector. Visual information (e.g., Radar and Flight Plans) automatically passes from one controller's position to the next.

### **7.4.1 Voice Switching and Control System (VSCS)**

On June 30, 1995, the FAA commissioned the first VSCS. This system provides air traffic controllers at air traffic control centers with air-to-ground and ground-to-ground voice communication capability. The VSCS is an integrated A/G and G/G voice and control communication switching system for Air Route Traffic Control Centers (ARTCC). The VSCS permits selection, interconnection, activation, and reconfiguration of communication paths between en route aircraft and other air traffic controllers.

The VSCS is designed to meet scalability and architectural limits [ 8] listed in Table 7-6.

**Table 7-6. VSCS Scalability and Architectural Limits**

Sizing Parameter	Initial Number Required		Maximum Future Sizing
	Minimum	Maximum	
Positions	50	340	430
Interfacility Trunks (Interphone)	50	450	570
Radio Interfaces	50	300	350
PABX Tielines	12	30	40
BUEC Interfaces	25	100	240

Additional capacity, given the current operating paradigm, will be required at the VSCS as the volume of A/G and G/G voice and control communication switching needs grows with the advent of increasing ROA operations and communications between air traffic controllers and aircraft.

### **7.4.2 Small Tower Voice Switch (STVS)**

The STVS is a digitally controlled switch providing non-blocking voice communications among air traffic control positions, radios, and phones. The system is modular and can be equipped to satisfy sites requirements. Table 7-7 shows an example of STVS scalability

and architectural limitations [ 18], based on a basic system size of 16 ports, expandable to 40 ports.

**Table 7-7. Example of STVS Scalability and Architectural Limitations**

Data Item	Basic	Expandable to
Number of operator ports	4	10
Number of radio ports	6	15
Number of telephone ports	6	15

#### **7.4.3 Rapid Deployment Voice Switch (RDVS)**

RDVS includes an integrated digital voice switching system that provides non-blocking voice communications between the air traffic control operator positions, radio channels, and interphone land lines. RDVS [ 19] is available in:

- Small Baseline System
- Large Baseline System (provides support to the Small Baseline System)

Table 7-8 describes the RDVS Small and Large Baseline systems scalability and architectural limitations. Enhancements introduce the Touch Entry Display (TED) features and the faster processor chip set/hardware; providing faster access speed capability for up to 200 air traffic controller positions respectively, also included in Table 7-8.

**Table 7-8. RDVS Scalability and Architectural Limitations**

Configuration Type	Number of Traffic Control Operator Positions
Small Baseline System	1 to 64
Large Baseline System	1 to 144
Faster Processor Chip Set/Hardware*	Up to 200

\*Currently available for selected RDVS models

### **7.5 ROA Communications**

ROA systems are capable of both direct line of sight communications with the ground station by a common data link or beyond line of sight through Ku band SATCOM:

- For direct line of sight capability: Support up to 274 megabits per second (although this is not currently supported)
- For Ku-band SATCOM: 50 megabits per second.

In the future users detached from the ground station could directly receive imagery data from the ROA.

The current UAV communications system architecture [ 9] can be viewed as four separate parts, some of which may use the same communications path(s) and RF Links.

1. Command and Control ( $C^2$ ) (Pilot-to-Aircraft, with telemetry from aircraft-to-pilot), anticipated to either be line-of-sight or Ku-band SATCOM. Ku-Band SATCOM, although higher in cost due to satellite transponder usage fees, can provide a means to alleviate congestion on ATC UHF or VHF capacity during peak activity periods. Rules and regulation must be created to rapidly reroute traffic during periods of high demand or congestive emergencies. Systems must be designed to rapidly respond to preemptive commands to vacate selected spectrum segments.
2. Air Traffic Control (UAV Pilot-to-FAA Air Traffic Control) communication, using one of two methods:
  - a. dial-up/leased line into an ATC facility. This method, when available, relieves congestion on ATC UHF or VHF capacity during peak activity periods. It is anticipated that a high degree of availability can be expected.
  - b. the aircraft  $C^2$  link to provide Pilot-to-UAV communications and then cross-link that voice transmission to the appropriate ATC UHF or VHF channel
3. Payload (mission traffic, such as surveillance information)
  - a. Depending on the amount of data volume the payload generates, this mode of communications has the highest potential for rapidly creating congestion in areas of close proximity to high communications traffic zones, and therefore should be closely monitored and regulated.
4. Flight Termination (onboard or remote emergency termination)

## 7.6 SATCOM Ku-Band Capacity

Geostationary satellite systems, stationed at 22,223 miles above the equator, provide needed Ku-band coverage to establish high-capacity links between ROAs and ground stations within the same Ku-band satellite transponder footprint. High-power, wideband Ku-band transponders are often used as passive repeaters to reflect a signal transmitted from ROAs back to earth. Ground earth stations equipped with appropriately sized parabolic antennas receive the transmitted information. Vast distances can separate the ground earth station from the ROA. Some satellite systems offer on-board signal processing for more efficient use of transponder and earth station resources.

Depending on the ROA nature and application, critical  $C^2$ , Air Traffic Control or Flight Termination communications may or may not be adversely affected by a high concentration of traffic over a Ku-band transponder. Ku-band capacity service can often be characterized as follows:

1. Non-preemptible Ku-band transponder capacity is designed to always be available for critical data or voice traffic except during weather or total satellite outage conditions
2. Additional transponder capacity on a different satellite reduces outage time due to spacecraft failure to a few hours per year, predominantly due to weather-related events, as covered next.

## **7.7 SATCOM Ku-Band Availability**

An inherent characteristic of Ku-band service is vulnerability to heavy rainfall. Satellite signals transmitted or received from a platform situated above rain clouds are unobstructed by rain. Satellite ground stations or aircraft flying below rain clouds may experience some drop in performance or a total outage condition, depending on the distance the signal has to travel through rain, and on the intensity of rainfall. Several techniques are available, although not always implemented, to compensate for rain attenuation, including: (a) uplink power control when transmitting from a ground station, or (b) ground station geographic diversity when the receive signal attenuation causes an outage at ground stations experiencing rain attenuation.

It is usually more difficult to compensate for satellite signal attenuation when transmit and receive signals at the ROA are affected by rain. One possible, although not always acceptable, alternative is to maintain or regain altitude to remain higher than rain clouds throughout the period of heavy rainfall. This would have the effect of both, maintaining Ku-band connectivity, as well as achieving landing within safer parameters, depending on the fuel level situation on-board the aircraft.

In most regions around the world, heavy rainfall with potential to disrupt Ku-band communications, rarely exceed:

- periods lasting more than ten or fifteen minutes at a time
- areas extending beyond a 20 to 40 mile radius at a given point in time

## **7.8 VHF Digital Link Mode 2 (VDL-2)**

VHF Digital Link Mode 2 (VDL-2) was conceived in the early 1990's as a method of providing high-speed bit-oriented digital data communications to aircraft. From the outset, VDL-2 was intended to support safety critical air traffic control communications. In addition, airline operational data would also be supported by VDL-2; a service traditionally supplied using ACARS (Aircraft Communications Addressing and Reporting System).

Internet Service Quality – VDL-2 operates at 31.5 kbit per second, providing a 10 fold increase in data throughput when compared with ACARS. ACARS is “character” oriented which means it communicates in a similar way to a telex machine and is only able to transfer letters and numbers. VDL-2, however, is “bit” oriented thus allowing the transfer of text and images leading to a service quality similar to that of the Internet.

Air traffic controllers use VDL-2 to communicate to aircraft using Controller to Pilot Data Link Communications (CPDLC).

### 7.9 Controller-Pilot Data Link Communications (CPDLC)

CPDLC uses a pre-defined set of instructions and responses that allow the pilot and controller to communicate safely and efficiently using a simple interface. Traditionally the controller instructs the pilot using voice, the pilot then reads back the instruction as confirmation of a correctly understood message. Even for a simple ATC instruction this process can take 20 seconds or more. Using CPDLC via VDL-2 the same instruction can be delivered and confirmed within a few seconds. The pilot and controller also have a permanent record of the message within their respective computer systems.

CPDLC essentially supplements the party line with a dedicated communications link for routine messages that make up to half of all controller/pilot communications. Multiple data messages can be sent out simultaneously compared to one-at-a-time method with voice-only communications. This has potential for not only reducing frequency congestion but also reducing many common miscommunications between pilots and controllers. Increased airspace capacity reflected by increased sector traffic throughput and reduced delay [ 20] is shown in Figure 7-2.

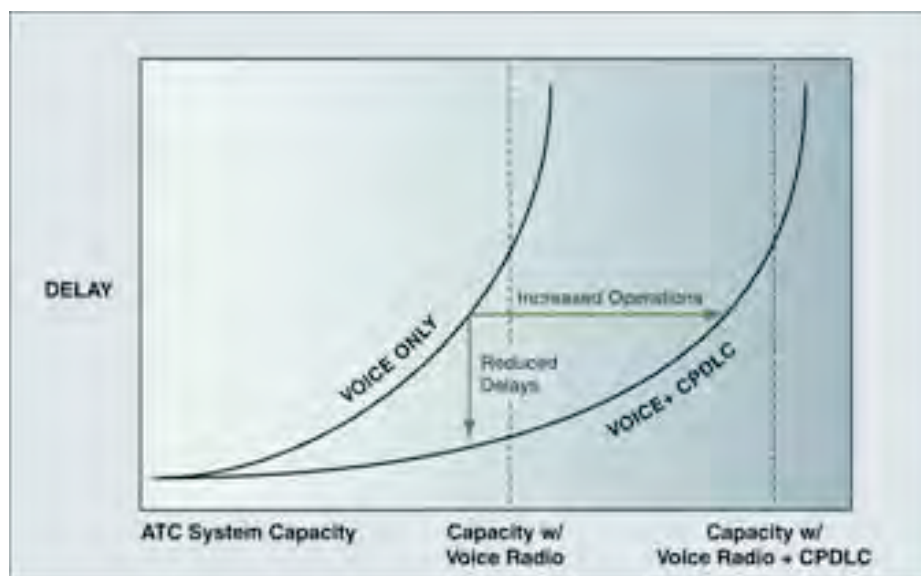


Figure 7-2 CPDLC Effects on Operations and Delays

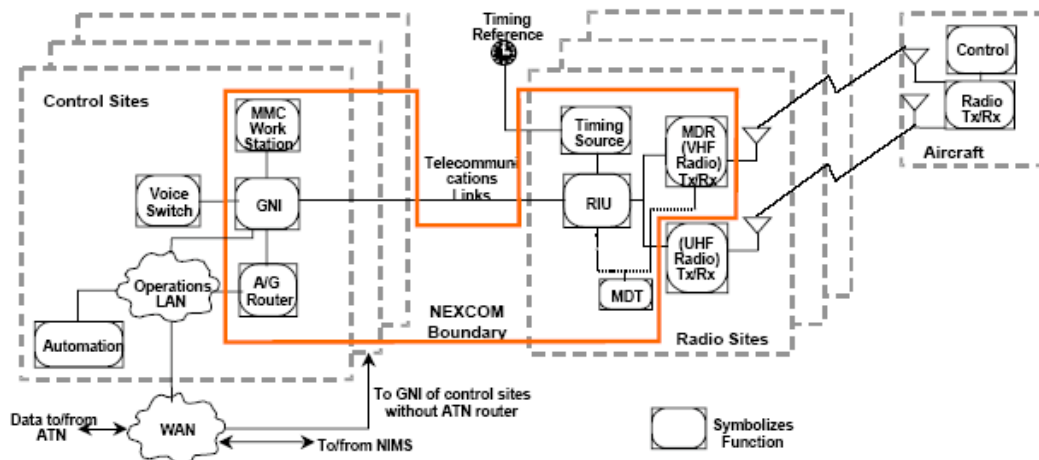
CPDLC augments voice communications for limited number of air traffic messages and can provide a second communications channel for use by the pilot and controller. It will augment the current voice communications capability, not replace it.

The FAA plans to deploy a CPDLC system that is ICAO compliant in ERM. Such a system is currently envisioned to be based on VDL-2 transport capabilities.

## 7.10 Next Generation Air/Ground Communication System (NEXCOM)

NEXCOM was the FAA radio system of the 21<sup>st</sup> Century. NEXCOM was an analog/digital system incorporating the latest technological advances in radio communications. NEXCOM planned to use VDL-3 technology to provide additional voice and data communications channels; NEXCOM was also planned to meet demanding ICAO requirements for high reliability and low latency. However, the FAA is currently reviewing options for NEXCOM outside of VDL-3.

NEXCOM was planned to provide the capability to accommodate additional sectors and services; reduce logistics costs; replace outdated VHF radios; provide data link communications capability; reduce Air/Ground Radio Frequency interference; and provide communication security mechanisms. A simplified representation of the NEXCOM system [ 10] is shown in Figure 7-3. In this context, VHF covers the frequency band between 117.975 and 137 MHz.



### Figure 7-3. Simplified Representation of the NEXCOM System

### 7.10.1 Channel Capacity

If NEXCOM is implemented with VDL-3, it will support at least 350 voice channels per ATC facility and may be expanded based on available frequency assignments.

### 7.10.2 VHF Digital Link Mode 3 (VDL-3)

Deployment of VDL-3 was envisioned by NEXCOM as the technology for the air/ground communication system, but is now being reexamined by the FAA. NEXCOM's VDL-3 capabilities has been canceled and is now being looked at as part of possible solutions for NGATS and future communications system studies being conducted jointly by the FAA, NASA Glenn Research Center and EUROCONTROL.

The VDL-3 system provides multiple channels to operate on one 25-KHz frequency assignment. The system will utilize Differential 8 Phase Shift Keying and employ 4.8 kilobits per second vocoders for voice operation. While current planning calls for

operating the system in a 2-voice/2-data configuration, other combinations are also supported. In the fully operational state, the system will accommodate both voice and data and will have the flexibility to determine how the channel resources are applied for voice and data.

VDL-3 has no broadcast restrictions (any receiver has access to the signal). In the point-to-point mode, where addressing is required, between 60 to 240 aircraft can be accommodated on a single frequency, depending on the specific configuration; example: 2 voice and 2 data channels accommodates 120 aircraft. Mode 3T is limited to 180 aircraft.

### **7.10.3 A/G Communications Improvements**

Additionally, the NAS will enhance operational efficiency and effectiveness through planned improvements to the A/G communications infrastructure that involve replacing aging and increasingly unreliable equipment and improving associated sites and facilities, including the establishment of new facilities intended to broaden communications coverage. The A/G Communications Infrastructure Program is the combination of the following projects:

- Communications Facilities Enhancements (CFE): designed to provide new radio control facilities and/or modify existing facilities to enhance the A/G communications between air traffic control and aircraft;
- CFE Limited Radio Replacement: Procure high-low VHF transmitters and receivers;
- Radio Interference (RFI) Elimination: designed to provide modern communication and ancillary equipment to improve operational performance at select remote communication facilities;
- Back-up Emergency Communications (BUEC): intended to provide a dedicated channel/sector in place of a priority based shared outlet system. The current 1970s system which is logistically unsupportable will be replaced.
- The Radio Control Equipment (RCE): planned to provide equipment used to control A/G radios from a remote location. Also planned is the replacement of maintenance intensive and logistically unsupportable vacuum-tube equipment.

## **7.11 NAS Telecommunications Services Evolves**

Telecommunications services within the NAS infrastructure are continuously being improved through an integrated approach. The FAA Telecommunications Infrastructure (FTI) acquires a wide range of contractor-provided service delivery points (SDP) to SDP telecommunications services with integrated network management and provisioning capabilities.

Over the next decade, FTI will incrementally replace existing NAS telecommunications systems. FTI reduces unit costs for telecommunications services, increase bandwidth

utilization, and improve efficiency and effectiveness by using modern business practices. FTI centralizes management and security functions and improves flexibility to support new and emerging air traffic systems.

## 7.12 Communications Systems Scalability and Architectural Limitations

Table 7-9 summarizes capacity provided by various NAS communications links (information includes excerpts from [ 11]).

**Table 7-9. Communications Systems Scalability and Architectural Limitations**

Data Link	Single Channel Data Rate (kbps)	Number of Channels Available to Aircraft	Maximum Number of Aircraft Sharing Channel	Comments
HFDL	1.8	1	50	Intended for Oceanic
ACARS	2.4	1	25	ACARS should be in decline as users transition to VDL Mode 2
VDL Mode 2	31.5	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	1	60	Deployment being reexamined
Mode-S	1000**	1	500	Intended for surveillance
UAT	1000	1	500	Intended for surveillance/FIS
Inmarsat's Aero H	9.6	1	1	Voice and data

\* Channel split between voice and data.

\*\* The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).



## **8 NAVIGATION AND WEATHER SYSTEMS**

Various types of air navigation aids are in use today, each serving a special purpose. These aids have varied owners and operators, namely: the FAA, the military services, private organizations, individual states and foreign governments. The FAA has the statutory authority to establish, operate, maintain air navigation facilities, and to prescribe standards for the operation of any of these aids which are used for instrument flight in federally controlled airspace.

Being passive for the most part, minimal impact is anticipated on navigation and weather systems due to ROA operations, unless otherwise noted in this section. Due to this fact, just a list of navigation and weather systems, is included in this section.

- WAAS (Wide Area Augmentation System)
- GPS (Global Positioning System)
- LORAN (Long-range Radio Aid to Navigation System)
- ILS (Instrument Landing System)
- NDB (Non-directional beacons)
- VOR (VHF Omnidirectional Range Navigation System)
- DME (Distance Measuring Equipment)

### **8.1.1 Weather radar systems**

Weather systems utilized in the NAS are provided in Table 8-1.

**Table 8-1. Air Traffic Volume Limitations for Weather Systems  
(Routing Number: ATB 420)**

<b><u>Product ID</u></b>	<b><u>Product Name</u></b>	<b><u>Prime Vendor</u></b>	<b><u>Air Traffic Volume Limitations</u></b>
LLWAS	Low Level Windshear Alert System	ALMOS, VAISALA, Vitrociset	These weather systems are passive and unaffected by air traffic volume levels
MIAWS	Medium Intensity Airport Weather System	Cancelled, Not Selected	
NEXRAD	Next-Generation Weather Radar	Lockheed Martin Other Manufacturers: Vaisala, Climatronics, RSIS, SIGMET	
TDWR	Terminal Doppler Weather Radar	Raytheon	
WSP	Weather Systems Processor	Northrop Grumman	The WSP is a subsystem of the ASR-9 (see radar systems)

## 9 SURVEILLANCE SYSTEMS

Current capacity limitations on common surveillance systems in use today are summarized in Table 9-1 and Table 9-2.

**Table 9-1. Air Traffic Volume Limitations for In Flight Primary Systems**

<b><u>Product ID</u></b>	<b><u>Product Name</u></b>	<b><u>Prime Vendor</u></b>	<b><u>Air Traffic Volume Limitations</u></b>
ARSR-1/2/3 & FPS	Air Route Surveillance Radar Models 1, 2, 3		800 targets (being replaced by the ARSR-4 system)
ARSR-4	Air Route Surveillance Radar Model 4	Northrop Grumman	800 targets per scan
ASR-11	Airport Surveillance Radar Model 11	Raytheon	700 targets minimum in a single scan
ASR-7/8 Digitizer	Airport Surveillance Radar Models 7 & 8	ITT, Westinghouse	For lower intensity airports (being replaced by the ASR-11)
ASR-9	Airport Surveillance Radar Model 9	Westinghouse/ Northrop Grumman	700 targets minimum in a single scan

**Table 9-2. Air Traffic Volume Limitations for In Flight Secondary Systems**

<b><u>Product ID</u></b>	<b><u>Product Name</u></b>	<b><u>Prime Vendor</u></b>	<b><u>Air Traffic Volume Limitations</u></b>
ATCBI-6	Air Traffic Control Beacon Interrogator	Raytheon	700 beacon targets, upgradeable to 1400
Mode S	Mode Select	Westinghouse/ Northrop Grumman Other Manuf.: Unisys	700 targets minimum in a single scan 32 Mode S targets in a 2.4 degrees beam dwell.
PRM	Precision Runway Monitor	Raytheon	35 tracks displayed at 1 sec update rate (including both real aircraft and false targets)

## **9.1 ADS-B (Automatic Dependent Surveillance-Broadcast)**

Automatic Dependent Surveillance – Broadcast (ADS-B), defined in RTCA/DO-242A, is a surveillance technology that enables applications that allow both pilots and controllers to have a common picture of airspace and traffic. ADS-B increases safety, capacity and efficiency.

ADS-B uses a combination of the 1090 MHz Extended Squitter ADS-B link for air carrier and private/commercial operators of high performance aircraft, and Universal Access Transceiver (UAT) ADS-B link for the typical general aviation user.

ADS-B airborne systems transmit an aircraft's identity, position, velocity, and intent to other aircraft and to air traffic control systems on the ground, thus allowing for common situational awareness to all appropriately equipped users of the national airspace system.

### **9.1.1 Flight Information Services - Broadcast (FIS-B)**

FIS-B is a ground broadcast service provided through the FAA's Universal Access Transceiver (UAT) "ADS-B Broadcast Services" network. The UAT network is an ADS-B data link that operates on 978 MHz, discussed later. The FAA FIS-B system provides pilots and flight crews of properly equipped aircraft with a cockpit display of certain aviation weather and flight operational information. FIS-B basically:

- Provide weather information in surrounding area of aircraft
- Provide icing altitude for the aircraft from ground station

In addition, FIS products may include surface observations and warnings in a text format and graphical products. Additional aeronautical data exchange will include Notices to Airmen (NOTAM) and information about lightning, icing, turbulence, volcanic ash, and

real-time Special Use Airspace (SUA). Document No. RTCA/DO-267A, Washington, DC, Minimum Aviation System Performance Standards (MASPS) describes the RTCA standard for the Flight Information Services-Broadcast (FIS-B) Data Link

### **9.1.2 Universal Access Transceiver (UAT)**

The UAT concept is designed for distribution of surveillance and weather data. It uses a unique hybrid access method of TDMA and random access. The TDMA portion is used to transmit the traffic and weather information while the random access portion is used by aircraft to transmit their own location in conformance with the RTCA DO-242 broadcast approach.

The system is included in the Safe Flight 21 initiative. The system operates on a UHF frequency of 978 MHz and provides for broadcast burst transmissions from ground stations and aircraft using a hybrid TDMA/random access scheme. The UAT message structure, net access scheme, and signal structure have been designed to support the RTCA DO-242 ADS-B MASPS (i.e., to transmit State Vector, Mode Status, and On-Condition messages and provide the corresponding ADS-B reports for use by operational applications).

RTCA/DO-282, dated August 27, 2002, covers “Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependant Surveillance—Broadcast (ADS-B).”

### **9.1.3 Mode S**

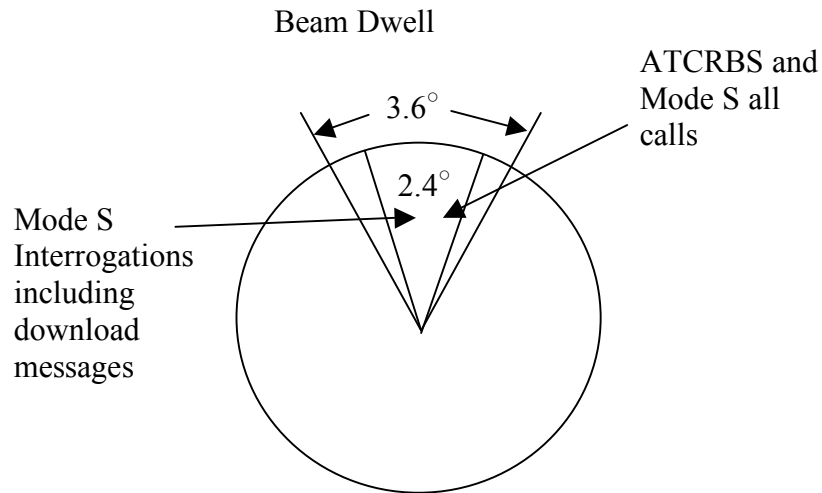
Mode S is an evolution of the traditional Secondary Surveillance Radar (SSR). For Mode S, each aircraft has a unique 24-bit address, which allows transmission selectively addressed to a single aircraft instead of broadcast to all aircraft in an antenna beam. The Mode S transponder has 56-bit registers which can be filled with airborne information such as aircraft speed, waypoint, meteorological information, and call sign. The information in the register can be sent either by an interrogation from the ground system or based on an event such as a turn.

For ADS-B, equipped aircraft can exchange information without a master ground station. Although capable of sending weather and other information, the Mode S communications capability is allocated to support of its surveillance role and will consist of aircraft position and intent. ADS-B uses the Mode S downlink frequency (i.e., 1090 MHz) and link protocols to squitter (i.e., spontaneously broadcast) onboard derived data characterizing the status (current and future) of own aircraft or surface vehicle via various ADS-B extended squitter message types (e.g., State Vector [position/velocity], Mode Status [identification/type category/current intent], and On-Condition [future intent/coordination data]).

Some of the impact an increase in ROA air traffic would have on Mode S is summarized in Table 7-9 for communications aspects, and also in Table 9-2, for surveillance aspects, provided later in this document.

Figure 9-1 depicts the number of Mode S targets a 2.4-degree beam dwell is limited to.

**Figure 9-1 Mode S Beam Dwell (2.4-Degrees) Target Limitations**



Beam Dwell is limited to more than 32 aircraft in 2.4 degrees.

## **9.2 Traffic Information System-Broadcast (TIS-B)**

TIS-B is the broadcast of traffic information to ADS-B equipped aircraft from ADS-B ground stations. The source of this traffic information is derived from ground-based air traffic surveillance sensors, typically radar. TIS-B service is becoming available in selected locations where there are both adequate surveillance coverage from ground sensors and adequate broadcast coverage from Ground Based Transceivers (GBTs). The quality level of traffic information provided by TIS-B is dependent upon the number and type of ground sensors available as TIS-B sources and the timeliness of the reported data.

TIS-B uses multilateration sensors and surface radar to identify positions of aircraft. TIS-B broadcasts secondary radar data from airport radars to aircraft for display in the cockpit. TIS is received via the Mode-S datalink available in new transponders or the Universal access transceiver (UAT) link, but can only show aircraft within radar coverage of airport surveillance radars (ASRs). TIS-B position updates will occur approximately once every 3-13 seconds depending on the radar coverage. In comparison, the update rate for ADS-B is nominally once per second).

TIS-B complement the surveillance information provided from ADS-B equipped aircraft. TIS-B detects aircraft without ADS-B.

Document No. RTCA/DO-286, Washington, DC, Minimum Aviation System Performance Standards (MASPS) describes the RTCA standard for Traffic Information Service-Broadcast (TIS-B).

### 9.3 Airport Surface Detection Equipment - Model 3 (ASDE-3)

ASDE-3 provides radar surveillance of aircraft and airport service vehicles at high activity airports. Radar monitoring of airport surface operations is required to aid in the orderly movement of aircraft and ground vehicles on the airport surface, especially during periods of low visibility such as rain, fog, and night operations. The ASDE-3 radar monitors aircraft on the airport surface, and works with the AMASS (Airport Movement Area Safety System) automated conflict alerting system to warn controllers about potential incidents.

AMASS is a computer enhancement to the FAA's current ground radar at major airports. It uses visual and audio alerts to warn controllers and protect against potential runway collisions. AMASS works by processing surveillance data from ground radar, then predicting possible conflicts based on the position, velocity and acceleration of arriving and departing aircraft and vehicles.

ASDE-3 is a primary radar. However, when AMASS is integrated with the ASDE-3 to form an ASDE-3A, the scalability and architectural limitations become those of AMASS.

**Table 9-3. ASDE-3A/AMASS Scalability and Architectural Limitations**

Data Item	Number of targets	Upgradable to	Prime Vendors
ASDE-3A	128	256*	Northrop Grumman Norden Systems

\* With extra processing elements

### 9.4 Airport Surface Detection Equipment - Model X (ASDE-X)

One element in the strategy to reduce operational errors and enhance safety in the NAS, ASDE-X is an airport surface surveillance system that provides seamless surveillance and aircraft identification to air traffic controllers. The system uses a combination of surface movement radar, transponder multilateration and ADS-B sensors to display aircraft position, labeled with flight call signs, on air traffic control tower displays. Under the ASDE-X program, the FAA plans to deploy the system at a number of the nation's airports.

The ASDE-X System is capable of tracking 200 combined real surface and approach (arrival) targets from sensor plot reports.

The ASDE-X system utilizes no more than 50% of Central Processing Unit (CPU) resources while processing 200 real targets in any configuration (Multilateration Sensor only; Radar Sensor only; both Radar and Multilateration Sensors), including processing for false targets, false plots, and other general processing necessary to maintain performance specifications. The ASDE-X system utilizes no more than 75% of CPU resources while processing 200 real targets in the System Enhancement configurations

identified in the specification (core system with Safety Logic causing 100 alerts per second; Multilateration Sensor and ASDE-3 primary radar with Safety Logic causing 100 alerts per second; and Dual Radar Sensors and Multilateration Sensor with Safety Logic causing 100 alerts per second), including processing for false targets, false plots, and other general processing necessary to maintain the performance specifications. System Control is realized from a minimum of three locations: the ATCT cab operator's positions, the equipment room and the ASDE-X control and monitoring system. Table 9-4 summarizes scalability and architectural limitations for the ASDE-X system [ 12].

**Table 9-4. ASDE-X Scalability and Architectural Limitations**

Data Item	Processing Capacity	Number of targets	Prime Vendors
Multilateration and/or Radar	50%	200	Sensis Corporation Other Manuf.: Raytheon
With Safety Logic	75%	200	

## 9.5 Airport Surface Detection Equipment - Model 3X (ASDE-3X)

Enhancements to the ASDE-X system allow it to interface with different surface movement radar and thus enable it to be deployed at more airports. This enhancement, called ASDE-3X, includes a joint probabilistic data association (JPDA) tracker. Table 9-5 summarizes scalability and architectural limitations for the ASDE-3X system [ 13].

**Table 9-5. ASDE-3X Scalability and Architectural Limitations**

Data Item	Scan Area	Number of targets	Prime Vendors
ASDE-3X	360 degrees	200*	Northrop Grumman Norden Systems

\* Aircraft and vehicles combined.



## 10 DOCUMENT SUMMARY

Scalability and architectural information covering ATC communications, surveillance and automation systems and tools, for en route or terminal environments, was examined, such as:

- Micro-EARTS, Common ARTS, HCS and their replacement systems and tools, including: STARS, ERAM, ATOP and URET to present radar data and/or flight plan information to enable air traffic controllers to monitor and control air traffic. Such systems currently have scalability and architectural issues that are, in some cases, being mitigated to successfully develop further capacity to meet future NAS requirements.
- Voice switching and data communications, including line-of-sight and global radio communications systems, including: VSCS, STVS, RDVS, VHF, UHF, NEXCOM, VDL-2, VDL-3, SATCOM, CPDLC,
- Navigation systems, including: WAAS, GPS, LORAN, ILS NDB, VOR, DME, and weather radar systems, were deemed to remain largely unaffected by expanded ROA operations.
- Radar and Surveillance including different models of: ARSR and ASR primary systems; ATCBI, Mode S, and PRM secondary systems; ADS-B; and ASDE.

## **11 RECOMMENDATIONS FOR FURTHER STUDY**

Recommendations for further study, covering safety and economic issues to effectively reduce airspace segregation between ROAs and manned aircraft, are included in this section.

### **11.1 Modeling**

A variety of different models, simulating terminal or en route air traffic, should be developed to support further analysis of the effects the different models would have on air traffic controllers, communications systems and surveillance systems, as currently deployed or as planned in the future.

Modelling will help to expose possible shortfalls in current or future NAS architectural features and capabilities in all flight regimes.

#### **11.1.1 Modeling Tool Enhancements**

Enhancements to existing tools may be needed to model ROA anticipated operations; requiring routes outside of traditional corridors but with potential intersect points.

Tools already exist for tracking, anticipating, and managing the flow of air traffic throughout U.S. airspace. En route modeling already plays an important role in congestion management planning.

These tools typically integrate real-time flight and weather data from multiple sources to present information either graphically or in statistical form, in order to assess susceptibility to congestion.

With adequate planning, challenges due to changing conditions, such as congestion, equipment outages, delays and weather are more effectively confronted.

One example of the need to model is when there is a need for several ROAs to operate on a race track pattern, and the potential to overload the Mode S sensors.

Also, depending on the number of ROAs aloft in a single TRACON airspace, en route and terminal systems may be at risk of exhausting the limited number of ATCRBS beacon codes available (4,096 codes).

### **11.2 Human-In-The-Loop Simulation**

#### **11.2.1 Relocation Modeling to Smaller and Underutilized Terminals**

Additional modeling could show the extent to which ROAs may or may not be good candidates for more efficient use of smaller and underutilized terminals. Modeling and simulation can be utilized to examine any improvement safety and economic advantages achieved by relocating an ROA base of operations to such terminals. Factors of interest could be as follows:

- Some economic factors might drive ROA operations to lower-cost terminal facilities, which might offer minimal passenger, crew and other high-cost accommodations seen at large terminals
- ROAs have no crew (on-board the ROA) or passengers who might be seeking proximity to urban destination
- Even when a large terminal is the ideal geographic destination, the additional time and fuel expended to reach a less optimal destination might be inconsequential compared to the higher cost burden of using runway, parking, maintenance, emergency and other facilities in place at the large terminals
- More flexibility might be associated with ROA operations in terms of rerouting during weather events since no crew or passengers have to shuttle from an alternate destination back to the original destination.

### **11.2.2 Modeling and Simulation of ROA Flight Scheduling**

Modeling and simulation may also demonstrate the extent to which ROA flight scheduling is or is not subject to the same constraints as manned flight scheduling – in other words, different parameters may govern schedule-related decisions on takeoff, landing and flight duration for these aircraft. This topic may:

- be the subject of further study;
- be addressed by the RTCA SC203; and
- include ROA operations outside of peak air traffic periods.

### **11.2.3 Air Traffic Controllers and CPDLC**

Today, sector capacity is limited by the complexity of the airspace and how many aircraft are within the span of control of the air traffic controller. Specific limits are maintained by the FAA in the form of lists kept by the Enhanced Traffic Management System (ETMS) at the Air Traffic Control System Command Center (ATCSCC) and at connected ETMS Facilities (i.e., ARTCCs and TRACONS).

Modeling and simulation of air traffic controllers, interacting with both manned and unmanned aircraft using CPDLC, could show the extent to which sector capacity, in terms of number of aircraft per sector, can be increased

Anecdotal evidence in domestic airspace showing that number of aircraft per sector could be increased by around 40% when CPDLC is available. This cannot easily be substantiated without significant modeling and human-in-the-loop simulation.

Today's process involves a query/reply scheme with the air traffic controller making direct contact with the aircraft crew over a voice channel. Queries originating from the air traffic controller often involve a modest waiting period before a reply is received from the aircraft crew. Current studies and operational experience with CPDLC at Miami ARTCC as well as with EUROCONTROL show that the voice-induced communications delays experienced by the air traffic controller can be eliminated permitting more aircraft to be served in a single sector.

## **12 REFERENCE DOCUMENTS AND OTHER SOURCES CONSULTED**

### **12.1 FAA and other Documents**

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- [ 2] Department of Transportation, Federal Aviation Administration, Microprocessor En Route Automated Radar Tracking System (Micro-EARTS) Computer Program Functional Specification, NAS-MD-674, EARTS System Overview, Change 5.7 (M) to Change 5.8 (M), August 2003.
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- [ 4] URET Daily - Use Metrics and Benefits, Analysis - Progress Report, MITRE, M P 0 0 W 0 0 0 0 1 6 4, Marilyn Walker, Paul Long, Niamh Lowry, August 2000.
- [ 5] Department of Transportation, Federal Aviation Administration, En Route Automation Modernization (ERAM), SYSTEM SPECIFICATION DOCUMENT, FAA-ER-XXXX, DRAFT, Version 1.5, November 24, 2003.
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[ 12] Department of Transportation, Federal Aviation Administration, National Airspace System (NAS) Subsystem Level Specification for Airport Surface Detection Equipment – Model X (ASDE-X), FAA-E-2942, Version 1.1, August 13, 2001.

[ 13] Verification Requirements Traceability Matrix for ASDE-3X, Version: Draft, Date: 27 September 2002, Doc. No. 700-009863, CDRL No: TE01, Contract #: DTFA01-01-C-00011.

## **12.2 Websites used in this study**

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[ 16] <http://www.faa.gov/and/and300/and360/index.htm>

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## **12.3 Interviews**

[ 21] Jeff Hobbs, FAA Program Manager for URET, on or around August 22, 2005

[ 22] Kevin Grimm, FAA Project Lead for ATOP, on or around August 24, 2005.



## ACRONYMS

ACARS	Aircraft Communications Addressing and Reporting System
ACE	Central Regional Headquarters
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
AFSS	Automated Flight Service Station
AK	Alaska
AMASS	Airport Movement Area Safety System
ARSR-1/2/3 & FPS	Air Route Surveillance Radar Models 1, 2, 3 and Fixed Position Surveillance
ARSR-4	Air Route Surveillance Radar Model 4
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Tracking System
ASDE-X	Airport Surface Detection Equipment - Model X
ASDE-3	Airport Surface Detection Equipment - Model 3
ASR-7/8	Airport Surveillance Radar Models 7 & 8
ASR-9	Airport Surveillance Radar Model 9
ASR-11	Airport Surveillance Radar Model 11
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATCSCC	Air Traffic Control System Command Center
ATCT	Air Traffic Control Tower
ATM	Air Traffic Manager
ATOP	Advanced Technologies and Oceanic Procedures
A/G	Air to Ground
BUEC	Backup Emergency Communications
CFE	Communications Facilities Enhancement
COTS	Commercial Off-The-Shelf
C <sup>2</sup>	Command and Control
CNS	Communications, Navigation, and Surveillance
CNS/ATM	Communications, Navigation, Surveillance / Air Traffic Management
CPDLC	Controller to Pilot Data Link Communications
CPU	Central Processing Unit
DASD	Direct Access Storage Device
DBRITE	Digital Bright Radar Indicator Tower Equipment
DHS	United States Department of Homeland Security
DME	Distance Measuring Equipment
DoD	United States Department of Defense
DSR	Display System Replacement
EBS	ERAM Back up System

EBUS	Enhanced Back-up Surveillance system
ECG	En Route Communications Gateway
EGPWS	Enhanced Ground Proximity Warning System
ERAM	En Route Automation Modernization
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FIS-B	Flight Information Services - Broadcast
FMC	Flight Management Computer
FPS	Fixed Position Surveillance
FTI	FAA Telecommunications Infrastructure
GHz	GigaHertz
GPS	Global Positioning System
G/G	Ground to Ground
HALE ROA	High-Altitude, Long-Endurance Remotely Operated Aircraft
HCS	Host Computer System
HOCSR	Host/Oceanic Computer System Replacement
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
INS	Inertial Navigation System
JPDF	Joint Probabilistic Data Association
KHz	KiloHertz
Ku-Band	SATCOM frequencies (uplink between 14 to 14.5 GHz and downlink between 11.7 to 12.7 GHz)
LLWAS	Low Level Windshear Alert System
LORAN	Long-Range Radio Aid to Navigation System
MHz	MegaHertz
MIAWS	Medium Intensity Airport Weather System
Micro-EARTS	Microprocessor-En Route Automated Radar Tracking System
MSAW	Minimum Safe Altitude Warning
M-1	(Plan View Display) Model 1
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASSRS	NAS System Requirements Specification (SR1000 Requirements)
NDB	Non-Directional Beacons
NEXCOM	Next Generation Air/Ground Communication System
NEXRAD	Next-Generation Weather Radar
NGATS	Next Generation Air Transportation System
NM	Nautical Mile
NOTAM	Notices to Airmen
OASIS	Operational And Supportability Implementation System
OEP	Operational Evolution Plan
PAMRI	Peripheral Adapter Module Replacement Item
PRM	Precision Runway Monitor
PSTN	Public Switched Telephone Network

RAPCON	Radar Approach Control
RCE	Radio Control Equipment
RF	Radio Frequency
RFI	Radio Frequency Interference
ROA	Remotely Operated Aircraft
RVR	Runway Visual Range
RWSL	Runway Status Lights
SAIC	Science Applications International Corporation
SATCOM	Satellite Communications
SC	Special Committee
SDP	Service Delivery Points
STAR	Standard Terminal Arrival Route
STARS	Standard Automation Replacement System
STVS	Small Tower Voice Switch
SUA	Special Use Airspace
TACAN	Tactical Air Navigation System
TCAS II	Terrain Collision Avoidance System
TDWR	Terminal Doppler Weather Radar
TIS-B	Traffic Information System - Broadcast
TRACON	Terminal Radar Approach CONTROL Facility
UAT	Universal Access Transceiver
UAV	Unmanned Aerial Vehicle
UHF	Ultra High Frequency
UNITE	UAV National Industry Team
VDL-3	VHF Digital Link Mode 3
VHF	Very High Frequency
VFR	Visual Flight Rule
VOR	VHF Omnidirectional Range Navigation System
VSCS	Voice Switching and Control System
WAAS	Wide Area Augmentation System
WSP	Weather Systems Processor